How safe are flexitanks?

Flexitanks provide a safe and cost-effective option for the transport of many bulk liquids. But how safe are they? And what effect do they have on the containers in which they are shipped? Flexitank engineer, **Theo Stahmeyer,** looks into some flexitank design and container safety issues

As fuel and road-toll costs continue to rise, and with ever-stricter safety and public health requirements, flexitanks are increasingly providing an important alternative to transporting liquids in tank containers, IBCs or drums. A number of flexitank producers have already successfully tackled the issue of hygiene and cleanliness, so as to avoid contamination either by bacteria or by chemical compounds. They offer flexitanks which have food approval certification or involve the use of food-approved materials and carry food grade products successfully.

In order to be as competitive as possible – and to offer their clients a favourable service at a low cost – flexitank operators and forwarders tend to offer the highest possible payload. In recent years, the trend has been towards the use of one-way flexitanks, with modern units underlining the need for cost reductions. The 'usual' load in a flexitank can be up to 24,000kg, but from a technical stand-point, it is important to know what the highest possible payload would be.

Rules and regulations

Although the flexitank is not yet specifically mentioned in most legislative documents, as a type of special packaging, the flexitank has to comply with many national and international regulations.

The transport and logistics industry considers that a flexitank is a 'bag-in-box' type of packaging – with the flexitank being the liquid-bag and the 20ft container being the box. By combining a flexible 'vessel' (the flexitank) and a rigid 'box' container, certain synergies can be obtained when transporting liquids. To a certain extent, flexitanks convert a standard 20ft dry freight ocean shipping container into a 'liquid container'. But, as ground storage flexitanks demonstrate, once they are filled, they do not naturally adopt the shape of a flexitank in a container.

The volume in a stand-alone ground storage flexitank is much lower than in a containerised flexitank. This is due to the lack of stiffness and strength of the flexitank. A flexitank has a more-or-less defined shape before loading; but the final shape depends on longitudinal and transverse dimensions, the strength, elongation and flexibility of the material used and the environment within the rigid container and its specific use. The shape depends also on the volume, density and temperature of the filled liquid.

The flexitank contains and holds the liquid, whilst the 20ft ISO container acts as both transport and storage equipment during the intermodal transport and handling chain. The container is designed and manufactured for general dry cargo in marine, on-road and rail throughout the world. It is built in accordance with technical requirements and has to meet the ISO recommendation 1496/1 and the Container Safety Convention (CSC), which set out minimum requirements. Flexitank transport has to conform to these rules.

The cargo weight distribution within the 20ft container should be balanced, so that the cargo's centre of gravity stays within the following limits:

Lengthwise:	maximum of 0.60m from centre of container
Crosswise:	at centre of container
Height:	beneath geometric centre of gravity of container

Importantly, these rules apply for dry freight and dry bulk goods, which can be secured by harness and straps, using precisely defined lashing rings at the bottom and roof of the container. The use of this equipment, well defined according to a lot of ISO or DIN-norms, helps to meet cargo weight distribution of dry bulk goods and to secure a safe transit.

What about flexitanks?

The flexitank is installed in a container and evenly distributed up to the filling height, with its borders being the bottom and the side walls of the container. The liquid puts pressure on the side walls. The top of the flexitank is primarily restricted by the upper surface of the flexitank. While the container is stationary, no change in the centre of gravity and no dramatic change to the static strains on the side-walls occur.

In this situation, the strength or flexibility of the flexitank's outer cover material is not important. But the reality is that a container does not primarily act as a means of storage, but of transportation, with different kinds of acceleration, movements, stresses and strains. Very often, flexitanks are mounted into the container without structural modification or the addition of harness straps and hooks. But the flexitank must remain within an admissible range under all operating conditions.

The rest of this article will focus on how static strains link up with dynamic strains, which inevitably arise during all types of movements.

Static stresses

According to the CSC (Convention for Safe Containers), the container has to meet the following test requirements for load strengths of side-walls, front-walls, door and roof:

- the side-walls must withstand loads of 0.6g, which corresponds to an evenly distributed load amounting to 60% of maximum payload;
- the end-walls must be designed to withstand loads of 0.4g (40% of the maximum payload), while the roof must withstand 300kg over a surface of 60 x 30cm.

Based on a 20ft container with a maximum payload of 28,230kg, the side-walls have a maximum permissible loading capacity of 16,938kg, and the front-wall and doors of 11,292kg. The doors must be secured by an appropriate bulkhead to reduce the stresses. In the case of a flexitank, a load of, for example, 24,.000kg is evenly distributed up to the filling height, but not evenly distributed over the full test-area according to the norm.

Practical tests with water-filled flexitanks imposed static stresses on the side-walls of the container (as shown in the graph in *Figure 1*). As bulk wine

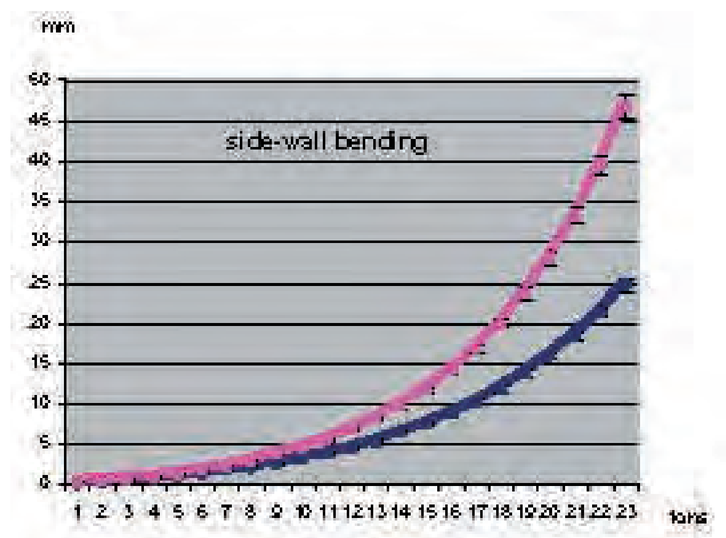
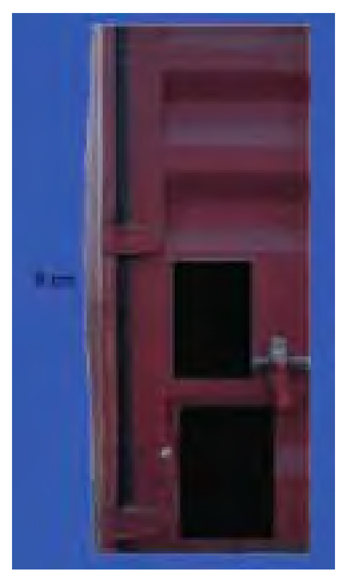


Fig 1: Side-wall bending of a container fitted with water-filled flexitanks



After a six-week journey, the side-walls bent up to 6 cm on either side of the container has similar characteristics to water – in terms of density, viscosity and temperature – test results can be transferred to this liquid. The curve, which shows the relation between weight and side wall deflection, is the result of permanent measurement during the filling process from one to 24 tons. In order to evaluate the overall impact on the side walls, left and right side walls were measured systematically in different areas. The curve shows the bending in the middle of the side walls, but bending results in the area of 90cm from corner posts were similar. The bending existed despite proper, careful and accurate assembly of the flexitanks into the container.

In certain extreme cases, with a bulk wine load of 24,000kg, after a six-week journey, the wall-expansion was between 6cm and 13cm on each side of the container *(see photo)*.

The pressure was not a result of the type – or even the size – of the flexitank; nor was it due to unprofessional installation (as some have suggested), nor the density of the liquid load. The high level of bending is also not a result of weak or pre-damaged side-walls, as the containers are normally selected carefully. It is the result of static stress and permanent dynamic stresses during transit time.

Operators and forwarders need to recognise that the bending will unavoidably deform the container's side-walls for a certain period of time. In many cases, it was observed that, after emptying the flexitank, there was no lasting deformation of the walls.

Dynamic stresses

The container has to withstand dynamic stresses, resulting from sea and land transport as well as from bulk and container handling. Because the container is closed during transit, no visual observation can be made of the cargo inside. Although the flexitanks have some stress absorption capability (depending on the material that is used), they do not prevent the liquid cargo from causing a greater or lesser degree of acceleration when turning corners, and shock during braking, shunting, vibration, handling, lifting or setting down.

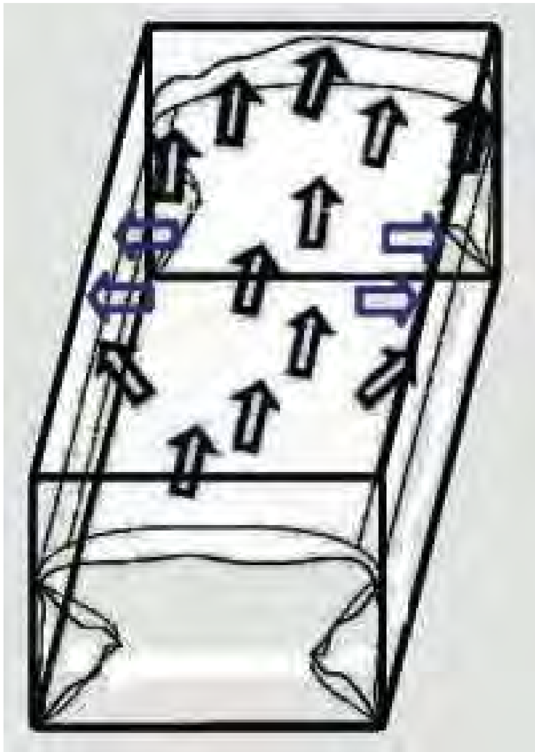


Fig 2: Surging and sloshing of liquids after braking and cornering, equating to a free-surface effect

The liquids being transported in flexitanks have different levels of density, viscosity and temperature. Depending on the size, shape, load and material of a flexitank, the liquid will therefore move in the course of shock and acceleration to greater or lesser degrees. For example, when loaded into the same kind of flexitank, it is clear that dispersion colours (with a density of 1.10kg/dm^3), or olive oil (with 0.93kg/dm^3), would behave differently than, say, wine or latex.

Obviously, a flexitank with a high elongation capability and low strength allows 'sloshing' and surging of the fluids that it contains - resulting in situations which are dangerous and out-of-balance. A higher temperature usually has a negative influence on the stress absorption capability of the flexitank, as the widely used thermoplastic materials tend to elongate under heat.

The risk of a dramatic move in the cargo's centre of gravity when turning are much higher during road transport, than when moving by road or rail. A flexitank positioned centrally at the bottom of a ship's hull behaves differently (in terms of acceleration) than on deck. Even if the worst case scenario of truck instability does not occur, there is permanent dynamic stress against the container walls. After sudden braking, truck drivers have reported a 'jump' of about 100-150cm of the entire truck-trailer-container vehicle, together with a visible permanent bending of the side-walls when turning on poor roads. Highly skilled drivers are required to counter extensive sloshing and surging - but even an excellent truck driver cannot compensate for poor flexitank quality.

Flexitank producers and operators have generally carried out strong braking tests using trucks and trains to develop reliable and durable products; but the focus has mainly been on just one part of the bag-in-box package – the flexitank. A lot of operators proudly present a proven track record for their flexitanks and praise the high elongation capability. The material is designed and constructed not to break in case of sudden shunt and the flexitank holds the liquid. The industry has invested a lot of money to develop and improve its product. But this is only one side of the coin.

Operators and forwarders have to realise that sudden braking causes dramatic stresses, involving powerful surging of the liquid, equating to a 'free-surface effect' and vehicle instability. Depending on the flexitank's type of material, its strength, size and shape – and particularly its stress absorption capability – it will deform the container side walls permanently.

It is normally not possible to know in advance how much acceleration will affect the container during a voyage. It is necessary not only to secure the load, but also to make sure the pressure is not too high in order to avoid damage. Point loads can easily result in major damage to the container walls. Flexitanks with high elongation and low strength characteristics will undoubtedly cause significant unbalanced conditions and vehicle instability.

The sketch in *Figure 2* demonstrates how the load can jump beneath the roof. Where point loads are expected or are unavoidable because of the behaviour of the loaded liquid, appropriate precautions must be taken.

Safety approval certificates?

In summary, it is clear that the different size, shape, strength and type of flexitank material and the range of liquids with different density, viscosity and temperature have greater or lesser influences on the static and dynamic stresses in an ISO container. Incorrect fitting and installation of a flexitank will contribute to unwanted deficiencies. Whether multi-ply or single-ply, it is a question of whether the flexitank has a sufficient stress absorption capability - if so it can avoid unwanted results.

The aim for flexitank producers and operators must be to minimise the negative impacts during flexitank transit; and to offer products which substantially eliminate fluid dynamic problems. Some years ago, when reusable flexitanks were much in use, it was normal to fit the tanks with five strap harnesses that lashed into hooks in the container floor, but this practice disappeared over recent years. Flexitank materials and their stress absorption qualities are one important part of the equation, but the size, shape and payload in the tank as well as the characteristics of the liquids themselves are all significant.

Flexitank producers and operators, shipping lines and forwarders need to consider all aspects of the 'bag-in-box' package. One of the major challenges for flexitank operators would be to offer their customers flexitanks with a safety approval certificate, which covers the complete bag-in-box package.